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Hexabromocyclododecanes (HBCDD) in Food

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Hexabromocyclododecanes (HBCDD) in Food

EXECUTIVE SUMMARY

Hexabromocyclododecanes (HBCDD) are additive flame retardants primarily used in textiles and expanded and extruded polystyrene applied as construction and packing materials. HBCDD are persistent in the environment, and have a strong potential to bioaccumulate and biomagnify (i.e. increasing concentration along the food chains).

2. The acute toxicity from exposure to HBCDD is low. In experimental animals, main targets for the chronic toxicity of HBCDD are the liver, thyroid hormone homeostasis, reproductive, nervous and immune systems. HBCDD are not genotoxic and not carcinogenic in experimental animals.

3. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has not evaluated the safety of HBCCD in food. The European Food Safety Authority (EFSA) adopted the margin of exposure (MOE) approach to assess the possible health concerns arising from the oral exposure to HBCCD. EFSA estimated a chronic intake of 2.35 mcg/kg bw/day of HBCDD in humans for MOE calculation, and considered that an MOE higher than 24 would indicate a low health concern.

4. This study serves (i) to determine the level of HBCDD in foods available in the local market; (ii) to estimate the dietary exposure to HBCDD of the Hong Kong adult population; and (iii) to assess the associated health risk.

Methods

5. A total of 300 individual samples (correspond to 100 food items) were collected locally. The samples were chosen mainly based on their local popularity, reported HBCDD levels in the literature, and availability in the local market. These samples were classified into 15 different food groups, including “Seawater fish”, “Freshwater fish”, “Fish products”, “Crustaceans”, “Molluscs”, “Meats and offals”, “Fats and oils”, “Drinks”, “Cereals and grains products”, “Milk and milk products”, “Eggs and eggs products”, “Vegetables and legumes”, “Fruits”, “Nuts and seeds” and “Herbs and spices”.

Results

6. Thirteen out of the total 15 food groups were found to contain HBCDD, including “Seawater fish” (38 out of 51 samples), “Freshwater fish” (19 out of 21 samples), “Fish products” (5 out of 9 samples), “Fats and oils” (16 out of 21 samples), “Molluscs” (12 out of 21 samples), “Milk and milk products” (8 out of 24 samples), “Meats and offals” (8 out of 30 samples), “Eggs and eggs products” (7 out of 9 samples), “Nuts and seeds” (6 out of 12 samples), “Cereals and grains products” (4 out of 27 samples), “Crustaceans” (2 out of 9 samples), “Vegetables and legumes” (2 out of 24 samples) and “Herbs and spices” (1 out of 9 sample). HBCDD were not detected in all samples of food groups “Drinks” and “Fruits”. In short, of the 300 samples analysed, 128 samples (about 43%) were found to contain HBCDD. Amongst these 128

samples detected with HBCDD, the levels ranged from 0.01 – 1.2 mcg/kg.

7. As regards the concentrations of HBCDD in different food groups, “Seawater fish” and “Eggs and eggs products” contained the highest mean levels of HBCDD, followed by “Molluscs” and “Freshwater fish”. The lower-bound mean concentrations of “Seawater fish”, “Eggs and eggs products”, “Molluscs” and “Freshwater fish” were 0.16 mcg/kg, 0.16 mcg/kg, 0.13 mcg/kg and 0.11 mcg/kg respectively.

8. Regarding the dietary exposure to HBCDD of the local adult population, the lower-bound (LB) and upper-bound (UB) exposure estimates of HBCDD for average consumers are 0.00016 and 0.00091 mcg/kg bw/day respectively while for high consumers (90th percentile), the LB and UB exposure estimates are 0.00041 and 0.0015 mcg/kg bw/day respectively. The corresponding MOEs for average and high consumers are in the ranges of 15000 – 2600 (LB-UB) and 5700 – 1600 (LB-UB) respectively. These MOEs are much higher than 24, indicating a low health concern.

9. The major contributor to the exposure of HBCDD is “Seawater fish” (30.7%), followed by “Freshwater fish” (21.2%), “Meats and offals” (20.1%), “Molluscs” (11.2%) and “Milk and milk products” (7.7%). Other food groups altogether contributed less than 10% to the total exposure.

Conclusion and Recommendations

10. In this study, HBCDD were detected in different samples, covering about 43% of samples collected.

11. Comparing the results of the current study with that of the other places, the dietary exposure to HBCDD of the local population is at the low end of the reported range of exposures. The calculated MOE values support the conclusion that current dietary exposure to HBCDDs for the Hong Kong adult population does not raise a health concern.

12. The findings of the dietary exposure to HBCDD in the present study do not warrant changes to the basic dietary advice on healthy eating. The public is advised to maintain a balanced and varied diet which includes a wide variety of fruits and vegetables.

Risk Assessment Studies –

Hexabromocyclododecanes in Food

OBJECTIVES

This study aims (i) to determine the level of hexabromocyclododecanes (HBCDD) in foods available in the local market; (ii) to estimate the dietary exposure to HBCDD of the Hong Kong adult population; and (iii) to assess the associated health risk.

BACKGROUND

2. Hexabromocyclododecanes (HBCDD) are additive flame retardants primarily used in textiles and in expanded and extruded polystyrene applied as construction and packing materials. HBCDD have a molecular structure in the form of a 12-carbon ring substituted with 6 bromine atoms. All HBCDD stereoisomers share the same chemical formula but differ from one another in the arrangement of bromine atoms around the 12-carbon ring (Figure 1)[1].

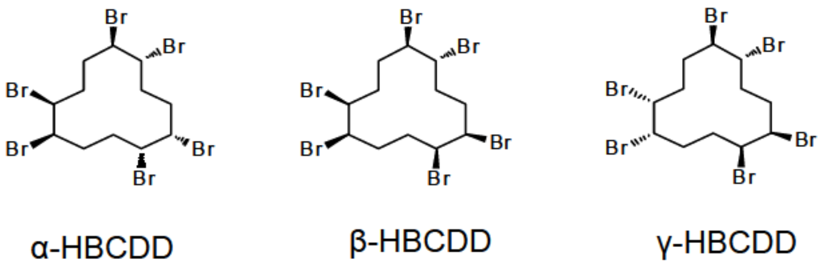

Figure 1. General structure of the three major HBCDD stereoisomers: α-HBCDD, β-HBCDD and γ-HBCDD.

3. HBCDD are persistent in the environment, and have a strong potential to bioaccumulate and biomagnify (i.e. increasing concentration along the food chains)[2,3]. Hence, there are concerns in the international arena (e.g. the United Nations Environment Programme), and among the national food safety authorities that HBCDD in the environment may eventually enter the food chain[4,5].

Occurrence in Food

4. According to the analysis of the European Food Safety Authority (EFSA), HBCDD have been detected in a wide range of food, such as seafood, meat, offal, dairy products, eggs, fats and oils, cereals, fruits and vegetables[1,4]. Besides, the proportion of non-detects in various food groups ranged from 33% to 100% for total HBCDD[1].

5. Although fatty foods of animal origin (e.g. meat, fish and egg) are more likely contaminated with HBCDD, some studies reported that plant-based food (e.g. vegetables, fruits and nuts) may also contain HBCDD at concentrations that are similar to that in meat and fish[4,6]. HBCDD in

plant-based food may arise from dust contamination during food preparation, direct absorption of HBCDD from the air, or the use of sewage sludge which contains HBCDD as fertilizer[4,7,29].

6. No data is available to show the effect of food processing on the HBCDD levels in foods. In general, HBCDD are chemically stable lipophilic substances. Reduction of HBCDD in processed foods may be mainly caused by the loss of fat, rather than the degradation of HBCDD[1].

Toxicity

7. Most of the toxicological studies were carried out using commercial preparation of HBCDD. Notably, the proportion of different isomers in the commercial HBCDD differs substantially from the HBCDD isomer profile found in food[1,8].

Toxicokinetics

8. Orally administered HBCDD are extensively absorbed and rapidly distributed in different tissues[9]. In general, HBCDD were found to concentrate in adipose tissues, muscles and liver[1,9]. Debromination and hydroxylation seem to be the major metabolic pathways for HBCDD. Stereoisomerisation of γ-isomer to α- and β-isomers was observed in mice treated with γ-HBCDD, but no stereoisomerisation was reported after exposure to α-HBCDD. Elimination half-life of HBCDD in humans was estimated to be 64 days (range 23-219 days)[1].

Acute toxicity

9. Acute toxicity from exposure to HBCDD is very low, and the LD_{50} value has not been determined. The oral lethal dose is more than 20 g/kg bw in rats, and exceeds 40 g/kg bw in mice[1,10].

Chronic toxicity

10. In experimental animals, main targets for HBCDD toxicity are liver, thyroid, reproductive, nervous and the immune systems. Animal tests showed that HBCDD possibly causes toxicity to human reproduction or development[11]. HBCDD are not genotoxic and carcinogenic in experimental animals[1].

Reproductive system

11. HBCDD were found to reduce fertility index and the number of ovarian primordial follicles, as well as the testes weight in rats[12]. EFSA concluded that HBCDD are not teratogenic or fetotoxic in rats[1].

Thyroid hormone homeostasis

12. Animal studies showed that HBCDD affect the thyroid hormone system. The most sensitive effect is increased relative thyroid weight in female rats. Moreover, changes in total thyroxine level, production of thyroid stimulating hormone in pituitary, as well as increased pituitary weight were observed in female rats[1,13].

Liver

13. Animal studies showed that HBCDD induce changes in hepatic

weight[13], gene expression, and function of liver[14,15]. HBCDD also induce changes in drug metabolism enzymes in liver, mainly CYP2 and CYP3, particularly of female rats[1,16].

Immune system

14. In rat, HBCDD were found to decrease splenocyte counts[13], lymphocyte fraction and whole white blood cell count in the blood[17]. Moreover, thymus and poplietal lymph node weight is increased, which is not accompanied by histopathological changes[1,17].

Nervous system

15. HBCDD can affect neurodevelopment. Of particular relevance is the behavioural changes indicating alterations in motor activity, and learning abilities reported after a single postnatal administration in mice[18]. The most relevant effects observed after repeated exposure seem to be sex-related, with hearing alterations occurring in male rats and changes in haloperidol-induced catalepsy most prominent in female rats[1,19].

Health-based Guidance Value

16. HBCDD was evaluated by EFSA in 2021[20]. EFSA considered that evidence from the available human data was not sufficient for the risk assessment of HBCDD, and the data from studies on experimental animals were used to identify a Reference Point for the human health risk characterisation. The neurodevelopmental effects on behaviour in mice

was considered the critical effect for the risk characterisation by EFSA, and a lowest observed adverse effect level (LOAEL) of 0.9 mg/kg bw in mice was identified, equivalent to a chronic human dietary intake of 2.35 mcg/kg bw/day, for the risk assessment of HBCDD[20].

17. Due to the limitations in the toxicological database on HBCDD (e.g. the lack of information on the stereoisomer composition of the HBCDD mixture tested in most studies), the derivation of a health-based guidance value (HBGV) was not considered appropriate[1,20,21]. Instead, the margin of exposure (MOE) approach was applied to assess possible health concerns, and a MOE higher than 24 would indicate a low health concern[20].

Regulatory Control

18. Codex has not established any food safety standard for HBCDD in food. There is no specific subsidiary legislation to regulate HBCDD in food in Hong Kong.

19. HBCDD were added to Annex A of the Stockholm Convention on Persistent Organic Pollutants (POPs) ("the Convention") in 2013[22]. The Convention is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment. Parties of the Convention must take

measures to eliminate the production and use of HBCDD. China has enacted the ban on manufacture, use and export of HBCDD since 2016, with the exception of the use of HBCDD as a flame retardant in polystyrene building materials, where the ban will commence on 2021 instead[23]. In Hong Kong, HBCDD are included in the Hazardous Chemicals Control Ordinance (Cap 595) (the Ordinance). Under the Ordinance, the manufacture, export, import and use of HBCDD are subject to permit control[24].

SCOPE OF STUDY

20. To estimate the dietary exposure to HBCDD of the Hong Kong adult population, this study analysed the levels of HBCDD in selected food items which were chosen mainly based on their popularity among the local adult population, their HBCDD levels reported in the literature, and their availability in the local market during the sampling period. These samples were classified into 15 different food groups, including "Seawater fish", "Freshwater fish", "Fish products", "Crustaceans", "Molluscs", "Meats and offals", "Fats and oils", "Drinks", "Cereals and grains products", "Milk and milk products", "Eggs and eggs products", "Vegetables and legumes", "Fruits", "Nuts and seeds" and "Herbs and spices".

METHODOLOGY AND LABORATORY ANALYSIS

Methodology

21. Food samples were collected between July and August 2020 from various retail outlets (including those in wet markets) such as supermarkets, grocery stores, etc. The list of food items analysed is listed in **Appendix II**. Only the edible portions of the samples would be analysed, and all samples, except flour, were prepared in the form of food "as consumed" before chemical analysis. The analytical results were then combined with food consumption information captured from the Hong Kong Population-based Food Consumption Survey (2005-2007) to obtain the dietary exposures of local adult population.

22. The estimation of dietary exposures was performed with the aid of an in-house developed web-based computer system, Exposure Assessment System (EASY). The mean and 90th percentile exposure levels were used to represent the dietary exposure levels of average and high consumers of the local population, respectively. The MOE value was calculated by dividing the reference dose of 2.35 mcg/kg bw/day by the estimated dietary exposure to HBCDD from food.

Laboratory Analysis

23. Laboratory analysis of HBCDD was conducted by the Food Research Laboratory (FRL) of the Centre for Food Safety. HBCDD analysis was conducted on an individual sample basis.

24. Levels of HBCDD in food samples were analysed by ultra-performance liquid chromatography - tandem mass spectrometry (UPLC-MS/MS). Stable isotope labelled HBCDD were spiked quantitatively into a measured amount of sample. Sample extraction was performed by ultra-sonication and orbital shaking with dichloromethane : n-hexane (1:1) and then purified by passing through a silica solid phase extraction (SPE) cartridge or an acidic silica SPE cartridge (for samples with high-fat content). After sample purification, the sample solution was concentrated and subjected to instrumental analysis. The limits of detection (LODs) of the individual stereoisomer of HBCDD was 0.01 mcg/kg.

Treatment of Analytical Values Below the LOD

25. In this study, analytical results were treated by the lower-bound (LB) and upper-bound (UB) approach, i.e. results below the LOD were assigned a value of zero or the value of LOD for the LB and UB, respectively[25]. This approach compares the two extreme scenarios, based on the consideration that the true value for results smaller than LOD may actually be any value between zero and the LOD. The LB scenario assumes the chemical is absent whilst the UB scenario assumes that the chemical is present at the level of the LOD.

RESULTS AND DISCUSSION

Occurrence of HBCDD

26. Of the 300 samples analysed, 128 samples (about 43%) were detected with HBCDD while the remaining 172 samples (about 57%) were not detected.

27. The 128 samples detected with HBCDD covered a wide range of food groups (i.e. 13 out of the total 15 food groups), including "Seawater fish" (38 out of 51 samples), "Freshwater fish" (19 out of 21 samples), "Fish products" (5 out of 9 samples), "Fats and oils" (16 out of 21 samples), "Molluscs" (12 out of 21 samples), "Milk and milk products" (8 out of 24 samples), "Meats and offals" (8 out of 30 samples), "Eggs and eggs products" (7 out of 9 samples), "Nuts and seeds" (6 out of 12 samples), "Cereals and grains products" (4 out of 27 samples), "Crustaceans" (2 out of 9 samples), "Vegetables and legumes" (2 out of 24 samples) and "Herbs and spices" (1 out of 9 sample). The levels of HBCDD in these samples ranged from 0.01 – 1.2 mcg/kg. In contrast, no samples in the food groups "Drinks" and "Fruits" were found to contain HBCDD. The mean HBCDD concentrations of food samples are shown in **Appendix II**.

28. As regards the concentrations of HBCDD in different food groups, "Seawater fish" and "Eggs and eggs products" contained the highest levels of HBCDD, followed by "Molluscs" and "Freshwater fish". The lower-bound mean concentrations of "Seawater fish", "Eggs and eggs products", "Molluscs" and "Freshwater fish" were 0.16 mcg/kg,

0.16 mcg/kg, 0.13 mcg/kg and 0.11 mcg/kg respectively. The concentrations of HBCDD in different food groups are summarised in Table 1, and the results of 300 food items are shown in **Appendix II**.

Table 1. Mean concentrations (mcg/kg) of HBCDD in different food groups

Food Group	No. of samples	% of samples <LOD	Mean of HBCDD (mcg/kg) [range]					
			Lower bound		Medium bound		Upper bound	
Seawater fish	51	25	0.16	[0-1.20]	0.17	[0.02-1.2]	0.18	[0.03-1.2]
Freshwater fish	21	10	0.11	[0-0.35]	0.12	[0.020-0.35]	0.13	[0.030-0.35]
Fish products	9	44	0.011	[0-0.030]	0.026	[0.020-0.040]	0.036	[0.030-0.050]
Crustaceans	9	78	0.0044	[0-0.030]	0.021	[0.020-0.030]	0.031	[0.030-0.040]
Molluscs	21	43	0.13	[0-0.74]	0.14	[0.020-0.74]	0.15	[0.030-0.74]
Meats and offals	30	73	0.044	[0-0.93]	0.061	[0.020-0.94]	0.071	[0.030-0.95]
Fats and oils	21	24	0.056	[0-0.26]	0.067	[0.020-0.26]	0.075	[0.030-0.26]
Drinks	12				< LOD in all samples			
Cereals and grains products	27	85	0.0019	[0-0.020]	0.020	[0.020-0.030]	0.030	[0.030-0.040]
Milk and milk products	24	67	0.0075	[0-0.040]	0.024	[0.020-0.050]	0.034	[0.030-0.060]
Eggs and eggs products	9	22	0.16	[0-0.89]	0.18	[0.020-0.90]	0.19	[0.030-0.91]
Vegetables and legumes	24	92	0.0013	[0-0.020]	0.020	[0.020-0.030]	0.030	[0.030-0.040]
Fruits	21				< LOD in all samples			
Nuts and seeds	12	50	0.011	[0-0.030]	0.026	[0.020-0.040]	0.036	[0.030-0.050]
Herbs and spices	9	89	0.0022	[0-0.020]	0.021	[0.020-0.030]	0.031	[0.030-0.040]

* Rounded to 2 significant figures. For easy comparison, the medium-bound (MB) level of HBCDD amount in food is also calculated, by assigning results below LOD as one half the LOD.

Dietary Exposure to Hexabromocyclododecanes

29. The dietary exposure estimates to HBCDD of the local adult population arising from the collected food items, and the corresponding MOE values are shown in Table 2. Regarding the dietary exposure to HBCDD of the local adult population, the lower-bound (LB) and upper-bound (UB) exposure estimates of HBCDD for average consumers are 0.00016 and 0.00091 mcg/kg bw/day while for high consumers (90th percentile), the LB and UB exposure estimates are 0.00041 and 0.0015 mcg/kg bw/day respectively. Their corresponding MOEs for average and

high consumers of the population are in the ranges of 15000 – 2600 (LB-UB) and 5700 – 1600 (LB-UB) respectively. These MOEs are much higher than 24, which indicate a low health concern.

Table 2. Dietary Exposure to HBCDD of Local Population and the Corresponding MOE values

	Average consumers	**High consumers**
Dietary Exposure (mcg/kg bw/day) (LB – UB)	0.00016 – 0.00091	0.00041 – 0.0015
MOE (LB-UB)	15000 – 2600	5700 – 1600

30. Further analysis of the dietary exposures of individual age-gender population subgroups is shown in Table 3. All the MOE values for average and high consumers are well above 24, indicating a low health concern for all age-gender subgroups.

Table 3. Dietary Exposure to HBCDD by Age-Gender Groups of Local Population

Age-Gender Group	**Dietary Exposure (mcg/kg bw/day)**	
	Average consumers (LB –UB)	High consumers (LB – UB)
Male aged 20-29	0.00012 –0.00084	0.00034 –0.0014
Female aged 20-29	0.00014 – 0.00083	0.00035 – 0.0014
Male aged 30-39	0.00014 –0.00088	0.00035 – 0.0014
Female aged 30-39	0.00017 – 0.00090	0.00040 – 0.0014
Male aged 40-49	0.00016 – 0.00095	0.00037 – 0.0015
Female aged 40-49	0.00018 – 0.00090	0.00043 – 0.0014
Male aged 50-59	0.00019 – 0.00099	0.00043 – 0.0015
Female aged 50-59	0.00019 – 0.00089	0.00042 – 0.0014
Male aged 60-69	0.00021 – 0.0010	0.00052 – 0.0016
Female aged 60-69	0.00019 – 0.00089	0.00054 – 0.0015
Male aged 70-84	0.00020 – 0.00096	0.00053 – 0.0015
Female aged 70-84	0.00019 – 0.00084	0.00043 – 0.0014

31. The CFS has recently completed the Second Hong Kong Population-based Food Consumption Survey. In view of (i) the levels of HBCDD detected in various local foods items in Hong Kong which are very low, and (ii) the high (1600 – 15000) MOEs calculated in this study which is many times higher than the MOE threshold of 24 (indicating that HBCDD in food is not a health concern in Hong Kong), the use of the second set of food consumption data in re-estimating the exposure levels is not expected to affect the results and conclusion of the study and may not be warranted.

Major Food Contributor

32. Relative contribution of different food groups to the overall HBCDD dietary exposure at LB estimation for an average consumer of the local adult population is shown in Table 4 and graphically in **Appendix I**. The LB is considered to better reflect the actual food group contribution to the overall HBCDD exposure since it is not influenced by the high numbers of samples below the LOD in some food groups.

Table 4. Average Dietary Exposure to HBCDD of Local Population and the Percentage Contribution of Different Food Groups

Food Group	Dietary Exposure (mcg/kg bw/day)	% Contribution to Dietary Exposure*
Seawater fish	0.000052	30.7%
Freshwater fish	0.000036	21.2%
Meats and offals	0.000034	20.1%
Molluscs	0.000019	11.2%
Milk and milk products	0.000013	7.7%

Fats and oils	0.0000045	2.6%
Eggs and eggs products	0.0000044	2.6%
Vegetables and legumes	0.0000037	2.2%
Cereals and grains products	0.0000021	1.2%
Nuts and seeds	0.00000063	0.4%
Crustaceans	0.00000026	0.2%
Fish products	0.000000073	0.04%
Herbs and spices	0.000000025	0.01%
Drinks	NA	NA
Fruits	NA	NA
Total	0.00017	100%

*May not sum to total due to rounding

33. In this study, the major contributor to the exposure of HBCDD is "Seawater fish" which contributed up to 30.7% (i.e. 0.000052 mcg/kg bw/day at the LB) of the total exposure, followed by "Freshwater fish" which contributed up to 21.2% (i.e. 0.000036 mcg/kg bw/day at the LB). Taking together, "Seawater fish", "Freshwater fish" and "Molluscs" contributed more than 70% to the total exposure. This is similar to the results of other studies, which also found aquatic products as the main dietary source of HBCDD[20,29,30,31]. Notwithstanding containing a relatively low mean concentration of HBCDD, "Meats and offals" contributes about 20.1% to the total exposure. This is likely due to the relatively high consumption amount of meats and offals by the Hong Kong adult population.

International Comparison

34. Dietary exposures of HBCDD have been reported in other places,

including mainland China[26], Ireland[27], the USA[28], Korea[29], Spain[30], Japan[31], Netherlands[32], Belgium[33], the United Kingdom[34], France[35] and the EU[1,20]. In general, all calculated MOE values in the aforesaid places were greater than 24. Comparing the results of the current study with that of the aforesaid places, the dietary exposures to HBCDD of the local population are in the low range.

Table 5. International Comparison of Dietary Exposure to HBCDD and MOE values

Places	Dietary exposure (mcg/kg bw/day)	MOE
United Kingdom[34]	0.0059	400
Japan[31]	0.006	400
Spain[30]	0.00258	900
Netherlands[32]	0.0015 (MB) – 0.0029 (UB)	1600 - 800
Mainland China[26]	0.00151	1700
Belgium[33]	0.00099	2400
Korea[29]	0.00082	2900
Ireland[27]	0.00043 (LB) – 0.00092 (UB)	5500 - 2600
USA[28]	0.00027	8700
France[35]	0.000165	14000
Hong Kong	0.00016 (LB) – 0.00091 (UB)	15000 - 2600
EU (EFSA)[1,20]	0.00009 (LB) – 0.00099 (UB) (2011) 0.00007 (LB) – 0.00152 (UB) (2021)	26000 – 2400 34000 - 1500

Uncertainties and Limitations of the Study

35. While higher accuracy and precision in exposure estimation could be achieved with more samples analysed, compromises had to be made in relation to the use of finite resources. In this study, only selected food items that were commonly consumed and reported more likely to contain HBCDD were sampled. Furthermore, the results of this study could only

represent a snapshot of HBCDD levels in certain locally available foods.

CONCLUSIONS AND RECOMMENDATIONS

36. In this study, about 43% of samples (128 out of 300 samples) collected were found to contain HBCDD. The food group "Seawater fish" is the major contributor to the dietary exposure of HBCDD for the local adult population.

37. Comparing the results of current study with that of the other places, the dietary exposure to HBCDD of the local population is at the low end of the reported range of exposures. The calculated MOE values support the conclusion that current dietary exposure to HBCDDs for the Hong Kong adult population does not raise a health concern.

38. The findings of the dietary exposures to HBCDD in the present study did not provide sufficient justifications to warrant changes to the basic dietary advice on healthy eating. The public is advised to maintain a balanced and varied diet which includes a wide variety of fruit and vegetables so as to avoid excessive exposure to any contaminants from a small range of food items.

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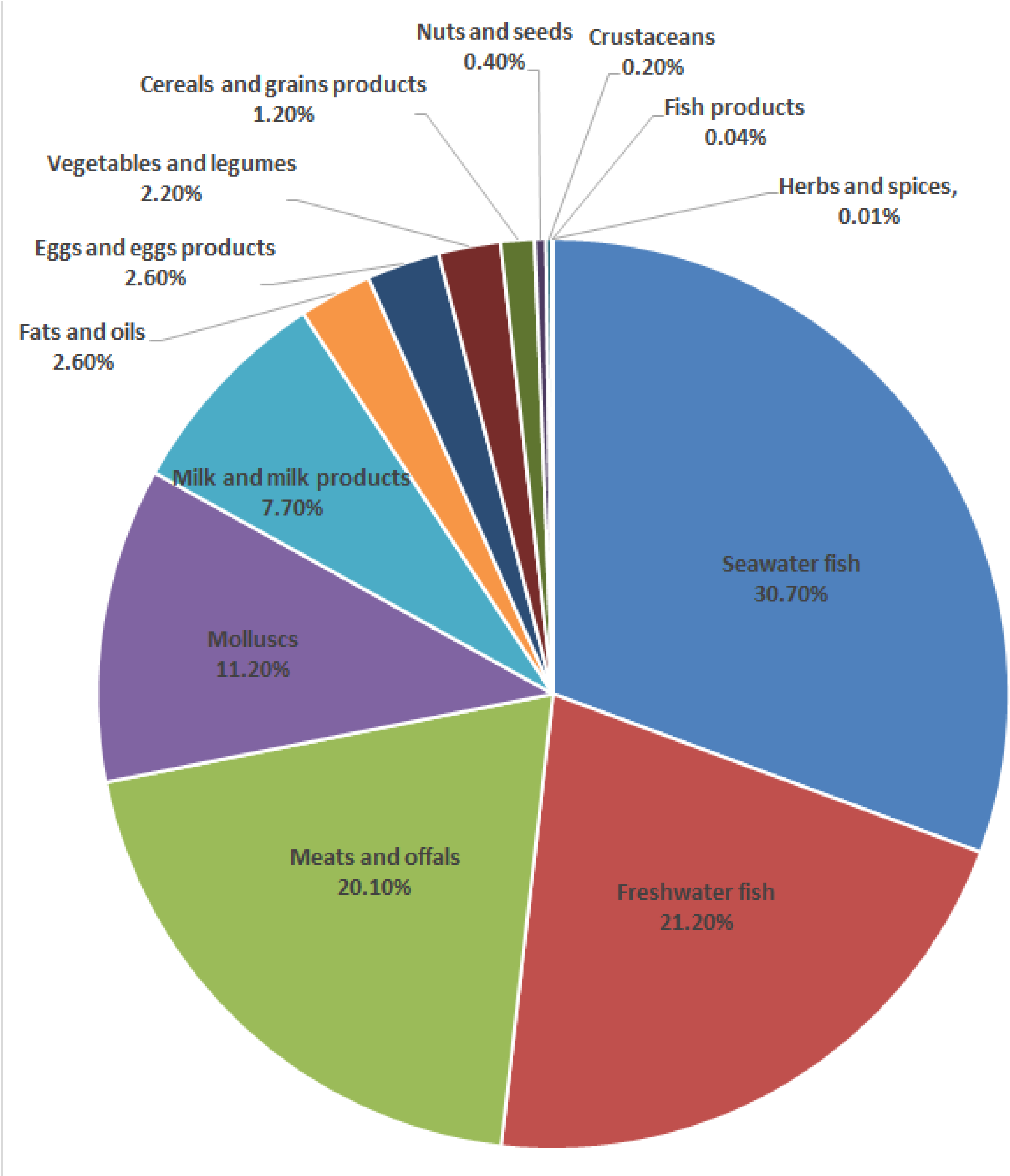
Appendix I

Relative Contribution of Food Groups to the Overall Dietary Exposure to HBCDD among Local Adult Population in Average



The LB data is used to better reflect the actual food group contribution to the overall HBCDD exposure since it is not influenced by the high numbers of samples below the LOD in some food groups.

Mean Levels of Hexabromocyclododecanes (mcg/kg) Detected in Food Samples

Food Item	No. of samples	% of samples <LOD	Mean of HBCDD (mcg/kg) [range]					
			Lower-bound		Medium-bound		Upper-bound	
Seawater fish	**51**	**25**	**0.16**	**[0-1.2]**	**0.17**	**[0.020-1.2]**	**0.18**	**[0.030-1.2]**
Green grouper	3				< LOD in all samples			
Golden thread	3	0	0.023	[0.020-0.030]	0.033	[0.030-0.040]	0.043	[0.040-0.050]
Horse head	3	0	0.020	[0.010-0.030]	0.030	[0.020-0.040]	0.040	[0.030-0.050]
Flounder	3	33	0.14	[0-0.34]	0.16	[0.020-0.35]	0.17	[0.030-0.36]
Pomfret	3	0	0.12	[0.050-0.19]	0.13	[0.060-0.20]	0.14	[0.070-0.21]
Yellow croaker	3	0	0.42	[0.33-0.50]	0.43	[0.34-0.51]	0.44	[0.35-0.52]
Capelin	3	0	0.090	[0.040-0.13]	0.10	[0.050-0.14]	0.11	[0.060-0.15]
Grey mullet	3	66	0.29	[0-0.88]	0.31	[0.020-0.88]	0.31	[0.030-0.88]
Bigeye	3	66	0.0067	[0-0.020]	0.023	[0.020-0.030]	0.033	[0.030-0.040]
Yellow-finned seabream	3	0	0.34	[0.21-0.45]	0.35	[0.22-0.46]	0.36	[0.23-0.47]
Turbot	3	0	0.17	[0.060-0.36]	0.18	[0.070-0.37]	0.19	[0.080-0.38]
Canned sardine	3	0	0.040	[0.020-0.070]	0.050	[0.030-0.080]	0.060	[0.040-0.090]
Mackerel	3	33	0.13	[0-0.25]	0.14	[0.020-0.26]	0.15	[0.030-0.27]
Cod	3	33	0.40	[0-1.2]	0.41	[0.020-1.2]	0.42	[0.030-1.2]
Salmon	3	0	0.083	[0.040-0.15]	0.087	[0.050-0.15]	0.097	[0.060-0.16]
Eel	3	0	0.48	[0.13-0.82]	0.49	[0.13-0.83]	0.50	[0.14-0.83]
Canned tuna	3				< LOD in all samples			
Freshwater fish	**21**	**10**	**0.11**	**[0-0.35]**	**0.12**	**[0.020-0.35]**	**0.13**	**[0.030-0.35]**
Grass carp	3	0	0.21	[0.19-0.23]	0.21	[0.19-0.23]	0.21	[0.19-0.23]

Freshwater grouper	3	0	0.19	[0.050-0.28]	0.20	[0.060-0.29]	0.21	[0.070-0.30]
Big head	3	0	0.16	[0.040-0.35]	0.17	[0.050-0.35]	0.18	[0.060-0.35]
Goldfish carp	3	0	0.097	[0.050-0.15]	0.10	[0.060-0.15]	0.11	[0.070-0.16]
Tilapia	3	0	0.053	[0.030-0.10]	0.063	[0.040-0.11]	0.073	[0.050-0.12]
Dace	3	0	0.063	[0.040-0.10]	0.070	[0.050-0.10]	0.080	[0.060-0.11]
Catfish	3	66	0.0033	[0-0.010]	0.020	[0.020-0.020]	0.030	[0.030-0.030]
Fish products	**9**	**44**	**0.011**	[0-0.030]	**0.026**	[0.020-0.040]	**0.036**	[0.030-0.050]
Fish ball/fish cake	3	33	0.010	[0-0.020]	0.023	[0.020-0.030]	0.033	[0.030-0.040]
Imitation crab meat	3				< LOD in all samples			
Fish skin (Fried)	3	0	0.023	[0.020-0.030]	0.033	[0.030-0.040]	0.043	[0.040-0.050]
Crustaceans	**9**	**78**	**0.0044**	**[0-0.030]**	**0.021**	**[0.020-0.030]**	**0.031**	**[0.030-0.040]**
Crab	3	66	0.010	[0-0.030]	0.023	[0.020-0.030]	0.033	[0.030-0.040]
Shrimp	3				< LOD in all samples			
Lobster	3	66	0.0033	[0-0.010]	0.020	[0.020-0.020]	0.030	[0.030-0.030]
Molluscs	**21**	**43**	**0.13**	**[0-0.74]**	**0.14**	**[0.020-0.74]**	**0.15**	**[0.030-0.74]**
Scallop	3	33	0.030	[0-0.050]	0.043	[0.020-0.060]	0.053	[0.030-0.070]
Abalone	3	66	0.013	[0-0.040]	0.030	[0.020-0.050]	0.040	[0.030-0.060]
Oyster	3	0	0.59	[0.30-0.74]	0.59	[0.30-0.74]	0.59	[0.31-0.74]
Clam	3	33	0.24	[0-0.55]	0.25	[0.020-0.55]	0.25	[0.030-0.55]
Mussel	3	33	0.040	[0-0.10]	0.053	[0.020-0.11]	0.063	[0.030-0.12]
Sea cucumber	3				< LOD in all samples			
Squid	3	33	0.013	[0-0.030]	0.023	[0.020-0.030]	0.033	[0.030-0.040]
Meats and offals	**30**	**73**	**0.044**	**[0-0.93]**	**0.061**	**[0.020-0.94]**	**0.071**	**[0.030-0.95]**
Beef	3	66	0.0033	[0-0.010]	0.020	[0.020-0.020]	0.030	[0.030-0.030]
Pork	3	66	0.0033	[0-0.010]	0.020	[0.020-0.020]	0.030	[0.030-0.030]
Mutton/ Lamb	3				< LOD in all samples			
Chicken meat	3	66	0.0033	[0-0.010]	0.020	[0.020-0.020]	0.030	[0.030-0.030]

Duck meat	3	33	0.38	[0-0.93]	0.39	[0.020-0.94]	0.40	[0.030-0.95]
Pigeon meat	3	0	0.050	[0.040-0.070]	0.060	[0.050-0.080]	0.070	[0.060-0.090]
Pig liver	3				< LOD in all samples			
Pig stomach	3				< LOD in all samples			
Pig large intestines	3				< LOD in all samples			
Cattle stomach	3				< LOD in all samples			
Fats and oils	**21**	**24**	**0.056**	**[0-0.26]**	**0.067**	**[0.020-0.26]**	**0.075**	**[0.030-0.26]**
Butter	3	0	0.023	[0.020-0.030]	0.033	[0.030-0.040]	0.043	[0.040-0.050]
Lard	3	0	0.14	[0.050-0.26]	0.15	[0.060-0.26]	0.15	[0.070-0.26]
Margarine	3	33	0.020	[0-0.040]	0.033	[0.020-0.050]	0.043	[0.030-0.060]
Peanut oil	3	0	0.073	[0.040-0.14]	0.083	[0.050-0.15]	0.090	[0.060-0.15]
Canola oil	3	66	0.0067	[0-0.020]	0.023	[0.020-0.030]	0.033	[0.030-0.040]
Olive oil	3	66	0.0067	[0-0.020]	0.023	[0.020-0.030]	0.033	[0.030-0.040]
Corn oil	3	0	0.12	[0.040-0.24]	0.12	[0.050-0.24]	0.13	[0.060-0.24]
Drinks	**12**				**< LOD in all samples**			
Bottled mineral water	3				< LOD in all samples			
Coffee	3				< LOD in all samples			
Bottled tea	3				< LOD in all samples			
Soybean milk	3				< LOD in all samples			
Cereals and grains products	**27**	**85**	**0.0019**	**[0-0.020]**	**0.020**	**[0.020-0.030]**	**0.030**	**[0.030-0.040]**
White rice	3				< LOD in all samples			
White bread	3	66	0.0033	[0-0.010]	0.020	[0.020-0.020]	0.030	[0.030-0.030]
Instant noodles	3				< LOD in all samples			
Spaghetti	3	66	0.0033	[0-0.010]	0.020	[0.020-0.020]	0.030	[0.030-0.030]
Macaroni	3				< LOD in all samples			
Flour	3				< LOD in all samples			
Oatmeal	3				< LOD in all samples			

Breakfast cereal	3				< LOD in all samples			
Saltine crackers	3	33	0.010	[0-0.020]	0.023	[0.020-0.030]	0.033	[0.030-0.040]
Milk and milk products	**24**	**67**	**0.0075**	**[0-0.040]**	**0.024**	**[0.020-0.050]**	**0.034**	**[0.030-0.060]**
Whole milk	3	33	0.020	[0-0.040]	0.033	[0.020-0.050]	0.043	[0.030-0.060]
Skim milk	3				< LOD in all samples			
Chocolate milk	3				< LOD in all samples			
Mozzarella cheese	3	33	0.0067	[0-0.010]	0.020	[0.020-0.020]	0.030	[0.030-0.030]
Whipping cream	3	33	0.013	[0-0.030]	0.027	[0.020-0.040]	0.037	[0.030-0.050]
Ice-cream	3				< LOD in all samples			
Plain yoghurt	3	66	0.010	[0-0.030]	0.027	[0.020-0.040]	0.037	[0.030-0.050]
Drinking yoghurt	3	66	0.010	[0-0.030]	0.027	[0.020-0.040]	0.037	[0.030-0.050]
Eggs and eggs products	**9**	**22**	**0.16**	**[0-0.89]**	**0.18**	**[0.020-0.90]**	**0.19**	**[0.030-0.91]**
Chicken egg	3	66	0.0033	[0-0.010]	0.020	[0.020-0.020]	0.030	[0.030-0.030]
Lime preserved egg	3	0	0.40	[0.12-0.89]	0.41	[0.13-0.90]	0.42	[0.14-0.91]
Salted duck egg	3	0	0.090	[0.050-0.16]	0.10	[0.060-0.17]	0.11	[0.070-0.18]
Vegetables and legumes	**24**	**92**	**0.0013**	**[0-0.020]**	**0.020**	**[0.020-0.030]**	**0.030**	**[0.030-0.040]**
Chinese flowering cabbage	3				< LOD in all samples			
Raddish	3				< LOD in all samples			
European lettuce	3				< LOD in all samples			
Tomato	3				< LOD in all samples			
Potato	3				< LOD in all samples			
Green peas	3				< LOD in all samples			
Winter mushroom	3	33	0.010	[0-0.020]	0.023	[0.020-0.030]	0.033	[0.030-0.040]
Tofu	3				< LOD in all samples			
Fruits	**21**				**< LOD in all samples**			
Orange	3				< LOD in all samples			
Apple	3				< LOD in all samples			

Banana	3				< LOD in all samples			
Pear	3				< LOD in all samples			
Watermelon	3				< LOD in all samples			
Pineapple	3				< LOD in all samples			
Grape	3				< LOD in all samples			
Nuts and seeds	**12**	**50**	**0.011**	**[0-0.030]**	**0.026**	**[0.020-0.040]**	**0.036**	**[0.030-0.050]**
Peanut	3	33	0.013	[0-0.020]	0.027	[0.020-0.030]	0.037	[0.030-0.040]
Chestnut	3				< LOD in all samples			
Lotus seed	3	33	0.013	[0-0.030]	0.027	[0.020-0.040]	0.037	[0.030-0.050]
Coconut milk	3	33	0.017	[0-0.030]	0.030	[0.020-0.040]	0.040	[0.030-0.050]
Herbs and spices	**9**	**89**	**0.0022**	**[0-0.020]**	**0.021**	**[0.020-0.030]**	**0.031**	**[0.030-0.040]**
White pepper	3	66	0.0067	[0-0.020]	0.023	[0.020-0.030]	0.033	[0.030-0.040]
Chinese parsley	3				< LOD in all samples			
Lemon grass	3				< LOD in all samples			

* Rounded to 2 significant figures. For easy comparison, the medium-bound (MB) level of HBCDD amount in food is also calculated, by assigning results below LOD as one half the LOD.